

AperTO - Archivio Istituzionale Open Access dell'Università di Torino

Mutation analysis of CHCHD2 and CHCHD10 in Italian patients with mitochondrial myopathy

This is the author's manuscript

Original Citation:

Availability:

This version is available <http://hdl.handle.net/2318/1663382> since 2019-01-18T12:17:43Z

Published version:

DOI:10.1016/j.neurobiolaging.2018.02.007

Terms of use:

Open Access

Anyone can freely access the full text of works made available as "Open Access". Works made available under a Creative Commons license can be used according to the terms and conditions of said license. Use of all other works requires consent of the right holder (author or publisher) if not exempted from copyright protection by the applicable law.

(Article begins on next page)

This is the author's final version of the contribution published as:

Rubino E, Zhang M, Mongini T, Boschi S, Vercelli L, Vacca A, Govone F, Gai A, Giordana MT, Grinberg M, Rogaeva E, Rainero I. Mutation analysis of CHCHD2 and CHCHD10 in Italian patients with mitochondrial myopathy. *Neurobiol Aging* 2018; doi: 10.1016/j.neurobiolaging.2018.02.007. [Epub ahead of print].

The publisher's version is available at:

[http://www.neurobiologyofaging.org/article/S0197-4580\(18\)30049-6/fulltext](http://www.neurobiologyofaging.org/article/S0197-4580(18)30049-6/fulltext)

When citing, please refer to the published version.

Mutation analysis of *CHCHD2* and *CHCHD10* in Italian patients with mitochondrial myopathy

Elisa Rubino^{a*}, Ming Zhang^{b*}, Tiziana Mongini^{a, c*}, Silvia Boschi^{a, d}, Liliana Vercelli^a, Alessandro Vacca^a, Flora Govone^a, Annalisa Gai^a, Maria Teresa Giordana^{a, c}, Mark Grinberg^b, Ekaterina Rogaeva^b, Innocenzo Rainero^{a, c}

a Department of Neuroscience "Rita Levi Montalcini", University of Torino, Torino, Italy

b Tanz Centre for Research in Neurodegenerative Diseases, University of Toronto, Toronto, Ontario, Canada

c Neurology 1, Department of Neuroscience and Mental Health, AOU Città della Salute e della Scienza di Torino, Torino, Italy

d Department of Neuroscience, Psychology, Drug Research and Child Health (NEUROFARBA), University of Florence, Italy

* These authors equally contributed to the manuscript

Corresponding author:

Elisa Rubino, MD, PhD

Department of Neuroscience "Rita Levi Montalcini", University of Torino

Via Cherasco 15, 10126 Torino, Italy.

Tel.: +39-011- 6634763

E-mail address: elisa.rubino@unito.it

ABSTRACT

Mutations in *CHCHD2* and *CHCHD10* were recently reported in a broad spectrum of neurodegenerative diseases, e.g. Parkinson's disease, amyotrophic lateral sclerosis, frontotemporal dementia or mitochondrial myopathy (MM). The aim of the study was to evaluate the prevalence of *CHCHD2* and *CHCHD10* mutations in Italian MM patients without mitochondrial DNA mutations. The coding regions of *CHCHD2* and *CHCHD10* were sequenced in 62 MM patients. None of the patients showed *CHCHD2* mutations, whereas one sporadic MM patient carried a homozygous Pro96Thr substitution in *CHCHD10*. Muscle biopsy of this patient showed intracellular glycogen accumulation with cytochrome c oxidase negative and ragged red fibers. Our study suggests that the homozygous Pro96Thr mutation in *CHCHD10* might be pathogenic, but does not support a major role for *CHCHD2* in MM pathogenesis.

KEYWORDS

Mitochondrial myopathy, *CHCHD10*, *CHCHD2*, Mitochondrial disease

Introduction

Mitochondrial myopathies (MM) can be caused by mutations in genes encoded by nuclear or mitochondrial DNA (mtDNA). A new family of mitochondrial (nuclear) proteins with a CHCH-domain and mitochondrial targeting sequence includes CHCHD2 and CHCHD10 that regulate oxidative phosphorylation, cytochrome c oxidase (COX) activity, and cristae morphology. *CHCHD10* mutations were recently reported in patients with amyotrophic lateral sclerosis (ALS) and/or frontotemporal dementia (FTD) (Bannwarth et al., 2014; Zhang et al., 2015). Intriguingly, patients from a French pedigree carrying a compound heterozygous *CHCHD10* *cis*-mutation (Arg15Ser/Gly58Arg) presented with a complex phenotype, including cerebellar ataxia, parkinsonism, MM, ALS or ALS/FTD (Ajroud-Driss et al., 2015). The ALS-causing Arg15Leu mutation destabilizes the CHCHD10 protein, leading to impaired cellular respiration and an increase in the steady-state level of CHCHD2 (Straub et al., 2017). Coding mutations in *CHCHD2* were reported in Japanese patients with an autosomal dominant Parkinson's disease (PD) (Funayama et al., 2015). *CHCHD2* variants (rs10043, rs142444896) were associated with sporadic PD, but not in Caucasians (Rubino et al., 2017). Here, we conducted a mutation analysis of *CHCHD2* and *CHCHD10* in Italian MM patients.

Methods

The exons of *CHCHD2* and *CHCHD10* were analysed by Sanger sequencing in 62 MM patients without mutations in mtDNA. The frequencies of the variants were compared to public databases. Histological study included hematoxylin/eosin and Gomori modified trichrome staining, as well as COX and succinate dehydrogenase (SDH) activity. Electron microscopy results were also available.

Results

In *CHCHD2*, we detected only a non-coding variant (rs10043, c.-9 T>G) in the 5' UTR (previously implicated in PD) with a minor allele frequency (MAF) of 0.289, which is similar to that reported in the 1000 Genomes database for the European population (MAF=0.223; p=0.197). Sequencing of *CHCHD10* showed a synonymous variant (rs111527940; c.234 G>A) in one patient, which is similar to the frequency in the European population (1000 Genomes). Furthermore, we identified a homozygous Pro96Thr substitution in exon 3 (rs111677724; c.307 C>A) (Supplemental Fig. 1). The frequency of rs111677724 in our dataset

(MAF=0.016) was significantly higher than in the European population from 1000 Genomes database (MAF=0.001; $p=0.012$) or the Exome Aggregation Consortium database (MAF=0.006), where only one homozygote was observed among 6013 individuals of European origin. This mutation is predicted to be deleterious by SIFT or possibly damaging by Polyphen 2.

Clinical information of the Pro96Thr carrier is available in the supplemental material. A muscle biopsy showed a typical pattern of MM as dystrophic features, several ragged red fibers, glycogen accumulation and 40% COX negative fibers (Supplemental Fig. 2) with a medium quantity of blood lactate (<4 mM). Electron microscopy showed aggregates of abnormal mitochondria with paracrystalline inclusions.

Discussion

In our MM cohort, we did not find any novel pathogenic *CHCHD2* mutations or any of the rare *CHCHD2* mutations previously reported in different neurological disorders. However, the analysis of *CHCHD10* revealed one MM patient with a homozygous Pro96Thr substitution in exon 3, which is 40 amino acids away from exon 2 (a hotspot for pathogenic mutations in *CHCHD10*) (Straub et al., 2017). This patient showed several ragged-red and COX-negative fibers associated with mitochondrial deletions at muscle biopsy, similar to previous findings in *CHCHD10* patients. The homozygous Pro96Thr mutation was previously described as pathogenic in three ALS patients of European origin (Dols-Icardo et al., 2015; Teyssou et al., 2016).

In conclusion, our data suggest that the homozygous Pro96Thr mutation in *CHCHD10* might be related to MM risk in some Italian patients, but do not support a major role of *CHCHD2* in MM pathogenesis. The limitation of the current study is the modest MM cohort; however, the patients were investigated with multiple methodologies including morphological, biochemical and molecular studies of muscle biopsies. Further investigation is needed to analyze the role of *CHCHD2* and *CHCHD10* in different populations.

Conflict of Interest

None of the authors has any conflict of interest to disclose.

Funding

This study was in part supported by the ALS Canada-Brain Canada Hudson Grant (ER) and AIRAlzh Onlus-ANCC-COOP (SB).

REFERENCES

- Ajrroud-Driss, S., Fecto, F., Ajrroud, K., Lalani, I., Calvo, S.E., Mootha, V.K., Deng, H.X., Siddique, N., Tahmoush, A.J., Heiman-Patterson, T.D., Siddique, T., 2015. Mutation in the novel nuclear-encoded mitochondrial protein CHCHD10 in a family with autosomal dominant mitochondrial myopathy. *Neurogenetics* 16, 1–9.
- Bannwarth, S., Ait-El-Mkadem, S., Chaussenot, A., Genin, E.C., Lacas-Gervais, S., Fragaki, K., Berg-Alonso, L., Kageyama, Y., Serre, V., Moore, D.G., Verschueren, A., Rouzier, C., Le Ber, I., Augé, G., Cochaud, C., Lespinasse, F., N’Guyen, K., de Septenville, A., Brice, A., Yu-Wai-Man, P., Sesaki, H., Pouget, J., Paquis-Flucklinger, V., 2014. A mitochondrial origin for frontotemporal dementia and amyotrophic lateral sclerosis through CHCHD10 involvement. *Brain* 137 (Pt 8), 2329-2345.
- Dols-Icardo, O., Nebot, I., Gorostidi, A., Ortega-Cubero, S., Hernández, I., Rojas-García, R., García-Redondo, A., Povedano, M., Lladó, A., Álvarez, V., Sánchez-Juan, P., Pardo, J., Jericó, I., Vázquez-Costa, J., Sevilla, T., Cardona, F., Indakoechea, B., Moreno, F., Fernández-Torrón, R., Muñoz-Llahuna, L., Moreno-Grau, S., Rosende-Roca, M., Vela, Á., Muñoz-Blanco, J.L., Combarros, O., Coto, E., Alcolea, D., Fortea, J., Lleó, A., Sánchez-Valle, R., Esteban-Pérez, J., Ruiz, A., Pastor, P., López De Munain, A., Pérez-Tur, J., Clarimón, J.; Dementia Genetics Spanish Consortium (DEGESCO), 2015. Analysis of the CHCHD10 gene in patients with frontotemporal dementia and amyotrophic lateral sclerosis from Spain. *Brain* 138 (Pt 12), e400.
- Funayama, M., Ohe, K., Amo, T., Furuya, N., Yamaguchi, J., Saiki, S., Li, Y., Ogaki, K., Ando, M., Yoshino, H., Tomiyama, H., Nishioka, K., Hasegawa, K., Saiki, H., Satake, W., Mogushi, K., Sasaki, R., Kokubo, Y., Kuzuhara, S., Toda, T., Mizuno, Y., Uchiyama, Y., Ohno, K., Hattori, N., 2015. CHCHD2 mutations in autosomal dominant late-onset Parkinson’s disease: a genome-wide linkage and sequencing study. *Lancet Neurol.* 14, 274-282.
- Rubino, E., Brusa, L., Zhang, M., Boschi, S., Govone, F., Vacca, A., Gai, A., Pinessi, L., Lopiano, L., Rogaeva, E., Rainero, I., 2017. Genetic analysis of CHCHD2 and CHCHD10 in Italian patients with Parkinson’s disease. *Neurobiol. Aging* 53, 193.e7-193.e8.

Straub, I.R., Janer, A., Weraarpachai, W., Zinman, L., Robertson, J., Rogaeva, E., Shoubridge, E.A., 2017.

Loss of CHCHD10-CHCHD2 complexes required for respiration underlies the pathogenicity of a CHCHD10 mutation in ALS. *Hum Mol Genet*. doi: 10.1093/hmg/ddx393.

Teyssou, E., Chartier, L., Albert, M., Bouscary, A., Antoine, J.C., Camdessanché, J.P., Rotolo, F., Couratier, P., Salachas, F., Seilhean, D., Millecamps, S., 2016. Genetic analysis of CHCHD10 in French familial amyotrophic lateral sclerosis patients. *Neurobiol Aging* 42, 218.e1-218.e3.

Zhang, M., Xi, Z., Zinman, L., Bruni, A.C., Maletta, R.G., Curcio, S.A., Rainero, I., Rubino, E., Pinessi, L., Nacmias, B., Sorbi, S., Galimberti, D., Lang, A.E., Fox, S., Surace, E.I., Ghani, M., Guo, J., Sato, C., Moreno, D., Liang, Y., Keith, J., Traynor, B.J., St George-Hyslop, P., Rogaeva, E., 2015. Mutation analysis of CHCHD10 in different neurodegenerative diseases. *Brain* 138 (Pt 9), e380.